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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(54) Title: METHOD AND DEVICE FOR COMPENSATION OF REACTIVE POWER

(57) Abstract

A device for compensation of the reactive power consumption of an industrial load (2), preferably an electric arc furnace or a plant for rolling of metallic materials, supplied from a three-phase (a, b, c) electric ac network (1), comprises a first compensation device (3) for controllable consumption of reactive power and a second compensation device (4) for generation of reactive power. The first compensation device comprises an inductor (31) connected in series with a semiconductor connection (32) controllable in dependence on a control order (αref) supplied thereto. Control equipment (7) is supplied with measured values of voltage (Ua, Ub, Uc) and current (Ia, Ib, Ic), respectively, at the load. The control equipment comprises means (8) for determination of the instantaneous consumption of active (P(t)) and of reactive power (Q(t)) by the load, and a control device (9) which forms the control order to the first compensation device in dependence on the consumption of reactive power and active power by the load.

Method and device for compensation of reactive power

TECHNICAL FIELD

5 The present invention relates to method for compensation of
the reactive power consumption of an industrial load, prefe-
rably an electric arc or a plant for rolling of metallic
material, supplied from an electric ac network, wherein a
first compensation device for controllable consumption of
10 reactive power, comprising an inductor series-connected to a
semiconductor connection which is controllable in dependence
on a control order supplied thereto, and a second compen-
sation device for generation of reactive power are both
connected to the electric power network in a parallel
15 connection with the load, and a device for carrying out the
method.

The device comprises a control device which forms the con-
trol order to the first compensation order in dependence on
20 the consumption of reactive power and active power by the
load.

BACKGROUND ART

25 Industrial loads connected to electric ac networks, in
particular arc furnaces but also, for example, rolling
mills, influence the voltage of the ac network, above all by
a greatly varying consumption of reactive power during
operation. Especially when the variations in power con-
30 sumption lie within a frequency interval of typically 0-20
Hz, the corresponding voltage variations, so-called flicker,
are observable and disturbing to the human eye in case of
electric lighting supplied by the ac network.

35 It is known, in connection with industrial loads of the
above-mentioned kind, to connect in parallel therewith, that
is, in a shunt connection to the ac network, static compen-
sators for compensation of the reactive power consumption of
the load. One type of such compensators usually comprises a

device for generating reactive power as well as a device for
controllable consumption of reactive power, known within the
art as a thyristor-controlled reactor (TCR). The device for
generation of reactive power usually comprises one or more

5 mutually parallel-connected filters, each one essentially
comprising an inductive element in series-connection with
capacitive elements. The filters are tuned to chosen multi-
ples of the nominal frequency of the ac network, for example
to the 3rd, 4th and 5th tones, sometimes even to the 2nd and

10 7th tones. The device for controllable consumption of reac-
tive power comprises an inductive element, an inductor, in
series-connection with a controllable semiconductor valve.
The controllable semiconductor valve comprises two controll-
able semiconductors, usually thyristors, in anti-parallel

15 connection. By phase-angle control of the semiconductors,
that is, by controlling their turn-on angle relative to the
phase position of the voltage of the ac network, the suscep-
tance of the device and hence its consumption of reactive
power can be controlled.

20
For a general description of thyristor-controlled reactors,
reference is made to Åke Ekström: High Power Electronics
HVDC and SVC, Stockholm June 1990, in particular to pages 1-
32 to 1-33 and 10-8 to 10-12.

25
The compensator generates a reactive power equal to that
generated by the device for generation of reactive power,
reduced by the consumption in the thyristor-controlled
reactor. By determining the instantaneous consumption of

30 reactive power by the load and then controlling the power
consumption of the thyristor-controlled reactor to such a
value that, together with the consumption of the load, it
corresponds to the reactive power generated by the device
for generation of reactive power, the reactive power

35 exchange with the ac network becomes zero.

European patent specification EP 0 260 504 describes a
circuit for compensation of reactive power comprising a
compensator and a load of the above-mentioned kind. In

addition thereto, this circuit comprises a self-commutated
converter, controlled in pulse-width modulation in depen-
dence on control signals generated in a control member, and
connected to the ac network in parallel connection with the
5   load and the thyristor-controlled reactor. The converter
supplies to the ac network a reactive current for compensa-
tion of the active and reactive power consumed/generated by
the load and the thyristor-controlled reactor. In an ortho-
gonal two-phase system, in dependence on sensed three-phase
10 currents and three-phase voltages, the control member calcu-
lates instantaneous values of the active and reactive power
consumed/generated by the load and the thyristor-controlled
reactor together.

15 In the above-mentioned patent specification, it is stated
that the voltage variations in the ac network are substan-
tially determined by variations in the reactive power con-
sumption of the load and that the voltage variations in
dependence on its active power consumption may be neglected.
20 The control signals to the converter are therefore formed
only in dependence on variations in the consumption of
reactive power by the load.

The method used in the above-mentioned patent for
25 determining the instantaneous active and reactive power of
the load in an orthogonal two-phase system is also
applicable for control of a thyristor-controlled reactor.
However, in this connection it has proved to be difficult
and in certain cases impossible, with the method for forming
30 a control signal as stated in the above-mentioned patent
specification, to meet the increasingly more stringent
demands on allowable disturbances imposed by the operators
of the ac networks.

35 SUMMARY OF THE INVENTION

The object of the invention is to provide a method of the
kind stated in the introductory part of the description, by

which the reduction of so-called flicker is improved, and a
device for carrying out the method.

According to the invention, this is achieved in that the
5   control order for the thyristor-controlled reactor is formed
in dependence on the consumption of active power by the
load.

Advantageous improvements of the invention will become clear
10   from the following description and claims.

Studies of compensators comprising thyristor-controlled
reactors have shown that improvements of their ability to
reduce flicker are achieved if their control orders are
15   formed according to the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described in greater detail by
20   description of embodiments with reference to the
accompanying drawings, wherein

Figure 1   schematically shows, as a single-line diagram, an
ac network with an industrial load and a device
25   according to the invention for compensation of the
reactive power consumption of the load,

Figures 2A and 2b
show embodiments of a control device in a device
30   according to Figure 1,

Figure 3   schematically shows, as a single-line diagram,
another embodiment of an ac network with an indus-
trial load and a device according to the invention
35   for compensation of the reactive power consumption
of the load, and

Figure 4   shows an embodiment of a control device in a
device according to Figure 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following description relates both to the method and the device. The device comprises calculating members, shown in
5   the figures as block diagrams, and it should be understood that the input and output signals to the respective blocks may consist of signals or calculating values. Signal and calculating value are therefore used synonymously in the following.
10

In order not to burden the presentation with distinctions self-explanatory to the man skilled in the art, generally the same designations are used for the currents, the voltages and the powers which arise in the compensation
15 device and the load as for the measured values and signals/calculating values, corresponding to the above-mentioned quantities, which are supplied to and processed in the control device described in the following.

20 Figure 1 shows , as a single-line diagram, a three-phase electric ac network 1 to which is connected an industrial load 2 in the form of an electric arc furnace. The arc furnace is connected to the ac network, via a transformer 12, at the busbar 11. Further, a general load 13 is
25 connected to the busbar, which load may comprise, for example, lighting networks in dwellings or offices. In parallel with the arc furnace, at a busbar 14, a first compensation device 3 for controllable consumption of reactive power and a second compensation device 4 for
30 generation of reactive power are connected.

The first compensation device comprises an inductor 31 connected in series with a controllable semiconductor connection 32, comprising two thyristors in anti-parallel
35 connection. The susceptance of the compensation device, and hence its consumption of reactive power, are controllable in a known manner by phase-angle control of the thyristors, that is, by control of their turn-on angle relative to the phase position for the voltage of the ac network.

The first compensation device of course comprises one inductor and one semiconductor connection per phase and its three phases are usually mutually connected in a Δ connection.

5

The second compensation device comprises a number of mutually parallel-connected filters, each one being tuned, in a manner known per se, to resonance with a certain multiple, tone, of the nominal frequency of the ac network,

10 for example its 3rd, 4th or 5th tone. For the sake of clarity, the figure only shows two filters 41 and 42, but it is to be understood that the second compensation device may comprise one or more filters of this type. Each one of the filters essentially comprises an inductive element in

15 series-connection with a capacitive element and this capacitive element generates a certain reactive power. The arc furnace and the compensation device are dimensioned in such a way, with respect to reactive power, that the second compensation device generates a power which, at least during

20 normal operation, exceeds the reactive power consumption of the arc furnace, and the first compensation device is controlled to consume a power such that, together with the consumption of the load, it corresponds to reactive power generated by the first compensation device. Viewed towards

25 the transformer 12, the reactive power consumption on the busbar 14 is then equal to zero. The second compensation device may also comprise a capacitor bank 43 in the event that the generation in the filters should be insufficient.

30 The voltages and currents for the three phases on the busbar 14 are designated Ua, Ub, Uc and Ia, Ib, Ic, respectively. In some manner known per se, the voltages Ua, Ub, Uc are sensed by means of a voltage-measuring device 5 and the currents Ia, Ib, Ic by means of a current-measuring device

35 6. The sensed values are supplied as measured values to control equipment 7, which, in dependence thereon, forms a control order αref which is supplied to the semiconductor connection 32. The control equipment comprises a calculating member 8 which, in dependence on the measured values of

sensed voltages and currents, forms calculating values of
the instantaneous active power P(t) of the arc furnace and
of its instantaneous reactive power Q(t), and further a con-
trol device 9 which, in dependence on the calculating values
5   of these powers, forms the control order.

The calculating member 8 forms, in some manner known per se,
the calculating values of active and reactive power on the
basis of the following known equations for transformation
10   from a three-phase system, the phases of which are designa-
ted a, b, c, to an orthogonal two-phase system, the phases
of which are designated d and q.

$$Ud + jUq = \bar{U} = 2/3\,[Ua + Ub \cdot e^{j2\pi/3} + Uc \cdot e^{-j2\pi/3}] \tag{1}$$

15

$$Id + jIq = \bar{I} = 2/3\,[Ia + Ib \cdot e^{j2\pi/3} + Ic \cdot e^{-j2\pi/3}] \tag{2}$$

$$P(t) = 3/2\ Re[\bar{U} \cdot \bar{I}*] = 3/2\,[Ud \cdot Id + Uq \cdot Iq] \tag{3}$$

20   $$Q(t) = 3/2\ Im[\bar{U} \cdot \bar{I}*] = -3/2\,[Ud \cdot Iq - Uq \cdot Id] \tag{4}$$

where $\bar{I}*$ designates the conjugate of the current vector $\bar{I}$
and Re and Im designate the real part and the imaginary
part, respectively, of the complex apparent power $[\bar{U} \cdot \bar{I}*]$.
25

The equation (4) expresses the reactive instantaneous power
consumption of the arc furnace and the task is to control
the first compensation device to a reactive power consump-
tion which together with the consumption of the arc furnace
30   balances the power generated by the second compensation
device. As mentioned above, the control of the first compen-
sation device takes place by controlling its susceptance,
here designated B. If the turn-on angle α of the thyristors
is defined relative to the phase position for the zero
35   crossing of the alternating voltage across the inductor,
maximum susceptance (with negative signs), and hence maximum
current through the inductor, is obtained for a = 90°, and
minimum susceptance (i.e. equal to zero) is obtained for a =

180°. The susceptance value whose magnitude is maximal thus amounts to B = -1/ωL, where L designates the inductance of the inductor and ω is the angular frequency of the ac network.

Between susceptance B and turn-on angle α the following well-known relationship applies:

$$B(\alpha) = - [2(\pi-\alpha) + \sin 2\alpha]/\pi\omega L \qquad (5)$$

and between the power Qr, consumed by the first compensation device, and its susceptance B, the following relationship applies:

$$Qr = - 3/2 * B * |\bar{U}|^2 \qquad (6)$$

where $|\bar{U}|$ designates the magnitude of the voltage vector $\bar{U}$ = Ud + jUq.

Figure 2A shows an embodiment of the control device 9 according to the invention. The control device comprises a signal-processing member 91, a summator 92, a summator 93, a quotient-forming member 94 and a function-forming member 95.

The output signal SQr from the summator 93 constitutes a calculating value of the reactive power which is to be consumed by the first compensation device and, according to the invention, this output signal is formed in dependence on, in addition to the reactive power Q(t) instantaneously consumed by the arc furnace, also in dependence on the active power P(t) instantaneously consumed by the arc furnace. This is achieved in the control device by supplying thereto values of the respective powers, calculated according to equations (3) and (4), whereupon a sum SQL is formed in the summator 92 in dependence on these values. The calculating value of the reactive power is supplied to the summator 92 whereas the calculating value of the active power is supplied to the signal-processing member 91, the output signal of which is supplied to the summator 92. The summator

93 forms the difference of a signal SQF, corresponding to
the power QF generated by the second compensation device,
and the signal SQL, which difference thus constitutes a
calculating value SQr of the reactive power which is to be
5   consumed by the first compensation device. By division of
the calculating value SQr by the factor $- 3/2 * |\bar{U}|^2$ in the
quotient-forming member 94, according to equation (6) a
reference value Bref for the susceptance of the first
compensation device is obtained. This reference value is
10   supplied to the function-forming member 95, which forms the
control order αref based on equation (5). It is assumed here
that the power QF generated by the second compensation
device is known as a function of the voltages Ua, Ub, Uc,
for example from data for elements included in the device.
15

The signal-processing member 91 is arranged with a transfer
function which makes the control device active in the
frequency interval which is of interest for reduction of
flicker. An interference curve specified in IEC Standard No.
20   868 (Flicker meter. Functional and design specifications),
weighed in dependence on the frequency, exhibits a maximum
at a frequency of about 8.8 Hz, and the control device
should therefore advantageously be active in an interval
around this frequency, preferably within a frequency inter-
25   val of 2 - 25 Hz. The signal-processing member is therefore
preferably given a phase-advancing (derivative) characteris-
tic within this interval and its transfer function H(s) may
advantageously comprise a term of the form

30   H(s) = K(1 + sT1)/(1 + sT2)   (7)

where s is the Laplace operator, K an amplification factor,
and T1 and T2, with T2 < T1, time constants corresponding to
the mentioned frequency interval.
35

Figure 2B shows an alternative embodiment of the control
device for those cases where the susceptance BF for the
second compensation device is known. The difference in
relation to the embodiment described with reference to

Figure 2A is that the output signal SQL from the summator 92
is supplied to the quotient-forming member 94, which, by
analogy with what has been described above, according to
equation (6), forms a calculated susceptance value SBL for
5   the arc furnace, corresponding to its instantaneous reactive
power consumption. The calculated susceptance value SBL and
a calculating value SBF of the susceptance of the second
compensation device are each supplied to an individual sign-
changing input of a summator 96, which forms the sum, with a
10 negative sign, of the signals SBL and SBF. This sum consti-
tutes the reference value Bref for the susceptance of the
first compensation device, which reference value is supplied
to the function-forming member 95.

15 Figure 3 shows an ac network with an industrial load and a
device according to the invention of a kind similar to that
in Figure 1 and where corresponding parts of the figure have
been given the same reference designations as in Figure 1.
The difference in relation to Figure 1 is that in this case
20 the currents Ia, Ib, Ic flowing to the parallel connection
of the ac furnace and the second compensation device are
sensed by means of the current-measuring devices 6. The cal-
culating values of instantaneous active and instantaneous
reactive power, formed by the calculating member 8, in this
25 case thus consist of the total active power PT(t) and the
total reactive power QT(t) of the mentioned parallel connec-
tion, that is, while assuming that the active power consumed
in the second compensation device is negligible, with the
previously used designations, P(t) = PT(t), whereas QT(t)
30 with reversed sign thus constitutes the calculating value
SQr of the reactive power which is to be consumed by the
first compensation device.

In this case, the control device may be designed as illu-
35 strated in Figure 4. The calculating value SQr, formed as a
sum, with a negative sign, of the calculating value QT(t)
and of the output signal from the signal-processing member
91, is supplied, as described with reference to Figure 2A,
to the quotient-forming member 94, the output signal of

which constitutes a reference value Bref for the susceptance
of the first compensation value. This reference value is
supplied to the function-forming member 95.

5   The control device according to the invention, described
above, is essentially active in the frequency range of
interest with respect to flicker, that is, typically in the
range of 2 - 25 Hz. As illustrated in Figures 1 and 3, the
function-forming member 95 is usually also supplied, in a
10   manner known per se, with a correction signal Pfd, formed in
a controller 10. The power factor Pf for transformer, load
and compensation device is sensed by means of a measuring
member 101 on the primary side of the transformer 12 and the
controller forms the correction signal Pfd in dependence on
15   a comparison between the sensed value of the power factor
and a prescribed reference value Pfref. The purpose of the
controller 10 is to maintain for the connected equipment an
average power factor according to agreement with the
electric power supplier. This mean value is usually speci-
20   fied over periods of 10 - 30 minutes, and this controller is
thus active in a considerably lower frequency range than the
device according to the invention.

The blocks shown in the block diagrams may, in appropriate
25   parts, be formed as a model comprising analog and/or digital
means for the modelling, or be completely or partially
carried out as calculations by means of analog and/or digi-
tal technique in hard wired circuits or be implemented as
programs in a microprocessor.
30

The invention is not limited to the embodiments shown. Thus,
within the scope of the invention, the calculating member 8
may be supplied only with sensed values of the currents Ia,
Ib, Ic and carry out the transformation $\bar{I} = Id + jIq =$
35    $2/3[Ia + Ib \cdot e^{j2\pi/3} + Ic \cdot e^{-j2\pi/3}]$ according to equation
(2). The instantaneous calculating values P(t) and Q(t) (as
well as PT(t) and QT(t)) described above are thus replaced
by calculating values of the instantaneous currents Id and
Iq, whereby the current Id is supplied to the signal-

processing member 91, the output signal of which, together
with the calculating value of the current Iq is summed into
a current reference value IQr for the first compensation
device. This current reference value can then be converted

5   into a reference value for reactive power by multiplication
in a multiplying member (not shown in the figures) by the
magnitude $3/2 * |\bar{U}|$ of the voltage vector $\bar{U} = Ud + jUq$,
whereupon the rest of the signal processing may take place
in a manner analogous to that described above.

10

As mentioned above, the first compensation device comprises
one inductor and one semiconductor connection per phase and
its three phases are usually interconnected in a Δ connec-
tion. The determination of the instantaneous consumption of

15 active and reactive power by the load may therefore advan-
tageously, in some manner known per se, be performed indivi-
dually for each phase in a Δ connection equivalent for the
load. Susceptance values are thereafter formed individually
for each one of the three phases of the first compensation

20 device in accordance with the method according to the
invention described above.

CLAIMS

1. A method for compensation of the reactive power consumpt-
ion of an industrial load (2), preferably an electric arc
5   furnace or a plant for rolling of metallic materials,
supplied from a three-phase (a, b, c) electric ac network
(1), wherein a first compensation device (3) for controll-
able consumption of reactive power and a second compensation
device (4) for generation of reactive power are both connec-
10 ted to the electric power network in a parallel connection
with the load, and the first compensation device comprises
an inductor (31) connected in series with a semiconductor
connection (32) controllable in dependence on a control
order (αref) supplied thereto, said semiconductor connection
15 comprising at least two controllable semiconductors in anti-
parallel connection, whereby the instantaneous consumption
of active (P(t)) and of reactive power (Q(t)) by the load is
determined, and the control order to the first compensation
device is formed in dependence thereon, **characterized** in
20 that a signal corresponding to said consumption of active
power is supplied to a signal-processing member (91) with a
phase-advancing characteristic in a frequency interval
surrounding the frequency 8.8 Hz, preferably in a frequency
interval of 2-25 Hz, and that the control order is formed in
25 dependence on an output signal from said signal-processing
member.

2. A method for compensation of the reactive power consump-
tion of an industrial load (2), preferably an electric arc
30 furnace or a plant for rolling of metallic materials,
supplied from a three-phase (a, b, c) electric ac network
(1), wherein a first compensation device (3) for controll-
able consumption of reactive power and a second compensation
device (4) for generation of reactive power are both connec-
35 ted to the electric power network in a parallel connection
with the load, and the first compensation device comprises
an inductor (31) connected in series with a semiconductor
connection (32) controllable in dependence on a control
order (αref) supplied thereto, said semiconductor connection

comprising at least two controllable semiconductors in anti-
parallel connection, whereby the total instantaneous con-
sumption of active power (P(t)) and of reactive power (Q(t))
by the load and the second compensation device is deter-
5   mined, and the control order to the first compensation
device is formed in dependence thereon, **characterized** in
that a signal corresponding to said total consumption of
active power is supplied to a signal-processing member (91)
with a phase-advancing characteristic in a frequency inter-
10   val surrounding the frequency 8.8 Hz, preferably in a
frequency interval of 2-25 Hz, and that the control order is
formed in dependence on an output signal from said signal-
processing member.

15   3. A method according to any of the preceding claims,
characterized in that said determination of instantaneous
consumption of active and of reactive power comprises a
transformation of values of current and voltages, sensed in
a three-phase system (a, b, c), to an orthogonal two-phase
20   system (d, q).

4. A method according to any of the preceding claims,
characterized in that said determination of instantaneous
consumption of active and of reactive power is performed
25   individually for each one of the phases in an equivalent Δ
connection and that the control order is formed individually
for each one of the phases of the first compensation device
in dependence on active and reactive power for the respec-
tive phase.
30
5. A device for compensation of the reactive power consumpt-
ion of an industrial load (2), preferably an electric arc
furnace or a plant for rolling of metallic materials,
supplied from a three-phase (a, b, c) electric ac network
35   (1), comprising a first compensation device (3) for con-
trollable consumption of reactive power and a second compen-
sation device (4) for generation of reactive power, voltage-
measuring devices (5) and current-measuring devices (6) for
sensing of voltage (Ua, Ub, Uc) and current (Ia, Ib, Ic),

respectively, at the load, and control equipment (7) which
is supplied with measured values of said sensed voltages and
currents, both said compensation devices being connected to
the electric power network in a parallel connection with the
5   load, the first compensation device comprising an inductor
(31) connected in series with a semiconductor connection
(32) controllable in dependence on a control order (αref)
supplied thereto, said semiconductor connection comprising
at least two controllable semiconductors in anti-parallel
10 connection, the control equipment comprising means (8) for
determination of the instantaneous consumption of active
(P(t)) and of reactive power (Q(t)) by the load, and a con-
trol device (9) which forms the control order to the first
compensation device in dependence thereon, **characterized**
15 in that the control device comprises a signal-processing
member (91) with a phase-advancing characteristic in a
frequency interval surrounding the frequency 8.8 Hz, prefe-
rably in a frequency interval of 2-25 Hz, which member is
supplied with a signal corresponding to said consumption of
20 active power, and that the control device forms the control
order in dependence on an output signal from said signal-
processing member.

6. A device for compensation of the reactive power consumpt-
25 ion of an industrial load (2), preferably an electric arc
furnace or a plant for rolling of metallic materials,
supplied from a three-phase (a, b, c) electric ac network
(1), comprising a first compensation device (3) for con-
trollable consumption of reactive power and a second com-
30 pensation device (4) for generation of reactive power, both
said compensation devices being connected to the electric
power network in a parallel connection with the load,
voltage-measuring devices (5) for sensing of voltage (Ua,
Ub, Uc) at the load and current-measuring devices (6) for
35 sensing of current (Ia, Ib, Ic) flowing to the parallel
connection of the load and the second compensation device,
and control equipment (7) which is supplied with measured
values of said sensed voltages and currents, the first
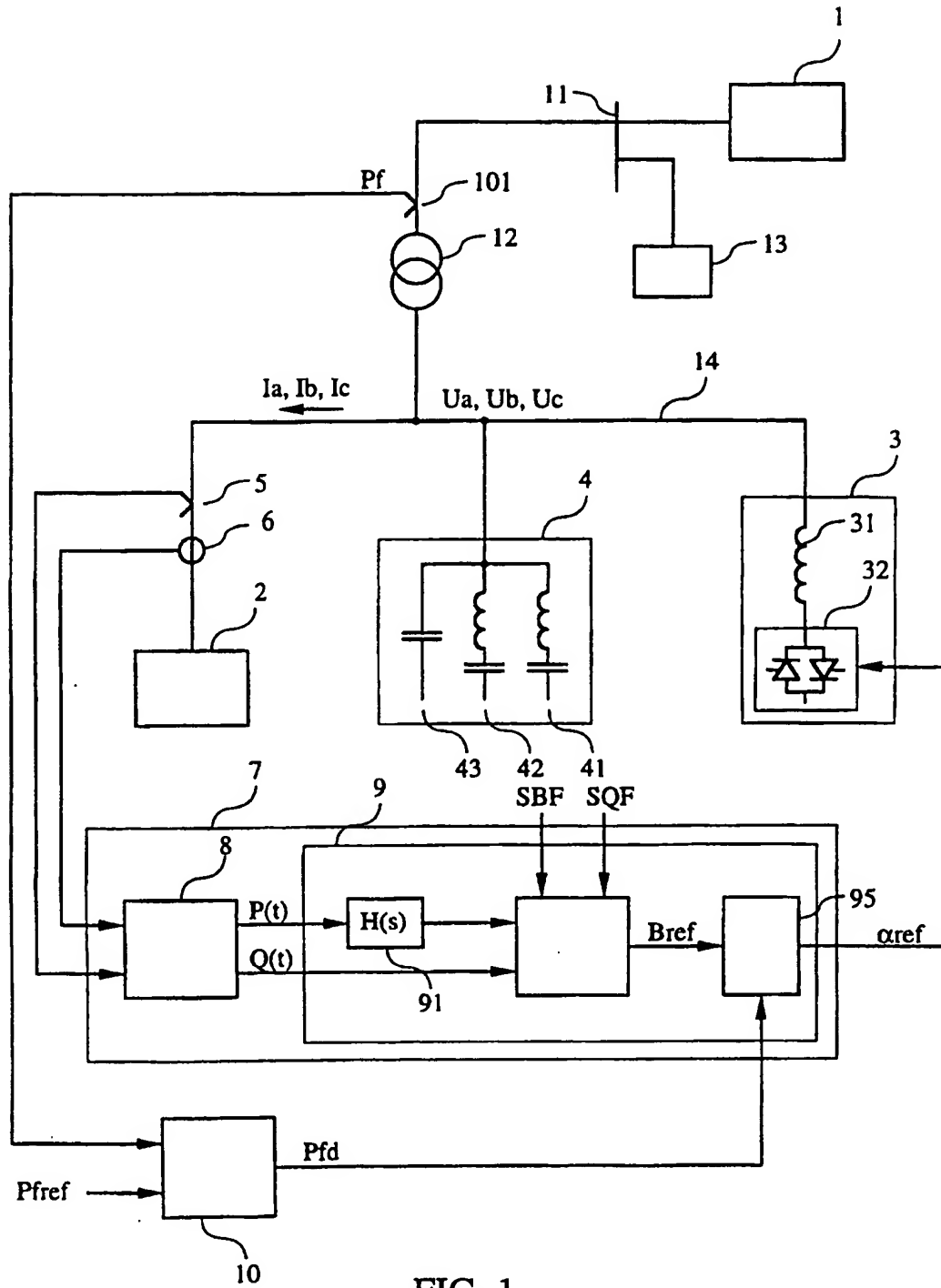compensation device comprising an inductor (31) connected in

series with a semiconductor connection (32) controllable in dependence on a control order (αref) supplied thereto, said semiconductor connection comprising at least two controll-able semiconductors in anti-parallel connection, the control equipment comprising means (8) for determination of the total instantaneous consumption of active power (P(t)) and of reactive power (Q(t)) by the load and the second compensation device, and a control device (9) which forms the control order to the first compensation device in dependence thereon, **characterized** in that the control device com-prises a signal-processing member (91) with a phase-advancing characteristic in a frequency interval surrounding the frequency 8.8 Hz, preferably in a frequency interval of 2-25 Hz, which member is supplied with a signal correspon-ding to said total consumption of active power, and that the control device forms the control order in dependence on an output signal from said signal-processing member.

7. A device according to any of claims 5-6, **characterized** in the transfer function (H(s)) of said signal-processing member(91) comprises a term of the form
H(s) = K(1 + sT1)/(1 + sT2), where s is the Laplace operator, K an amplification factor and T1 and T2, with T2 < T1, time constants corresponding to said frequency interval.

8. A device according to any of claims 5-7, **characterized** in that the means (8) for determination of said instan-taneous consumption of active and of reactive power during this determination carry out a transformation of values of current and voltages, sensed in a three-phase system (a, b, c), to an orthogonal two-phase system (d, q).

9. A device according to any of the claims 5-8, **characterized** in that the means (8) for determination of said instantaneous consumption of active and of reactive power carry out this determination individually for each one of the phases in an equivalent Δ connection and that the control equipment forms the control order individually for each one of the phases of the first compensation device in

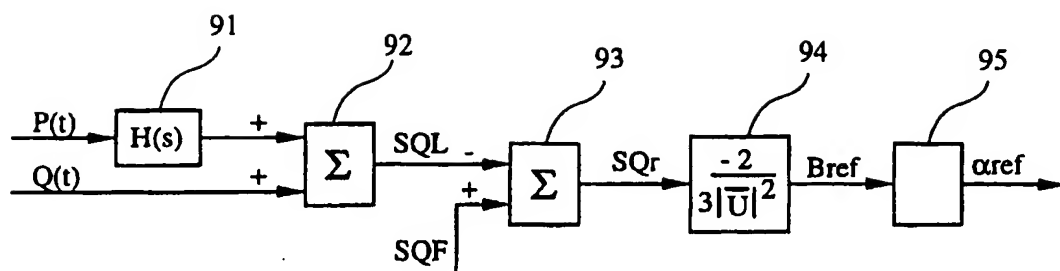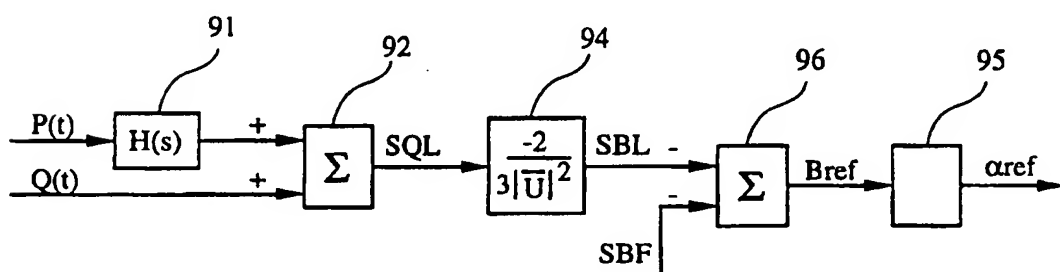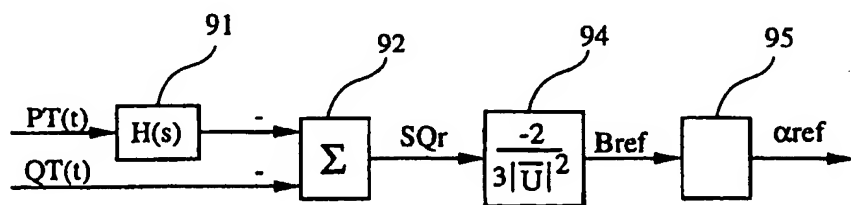dependence on active and reactive power for the respective phase.
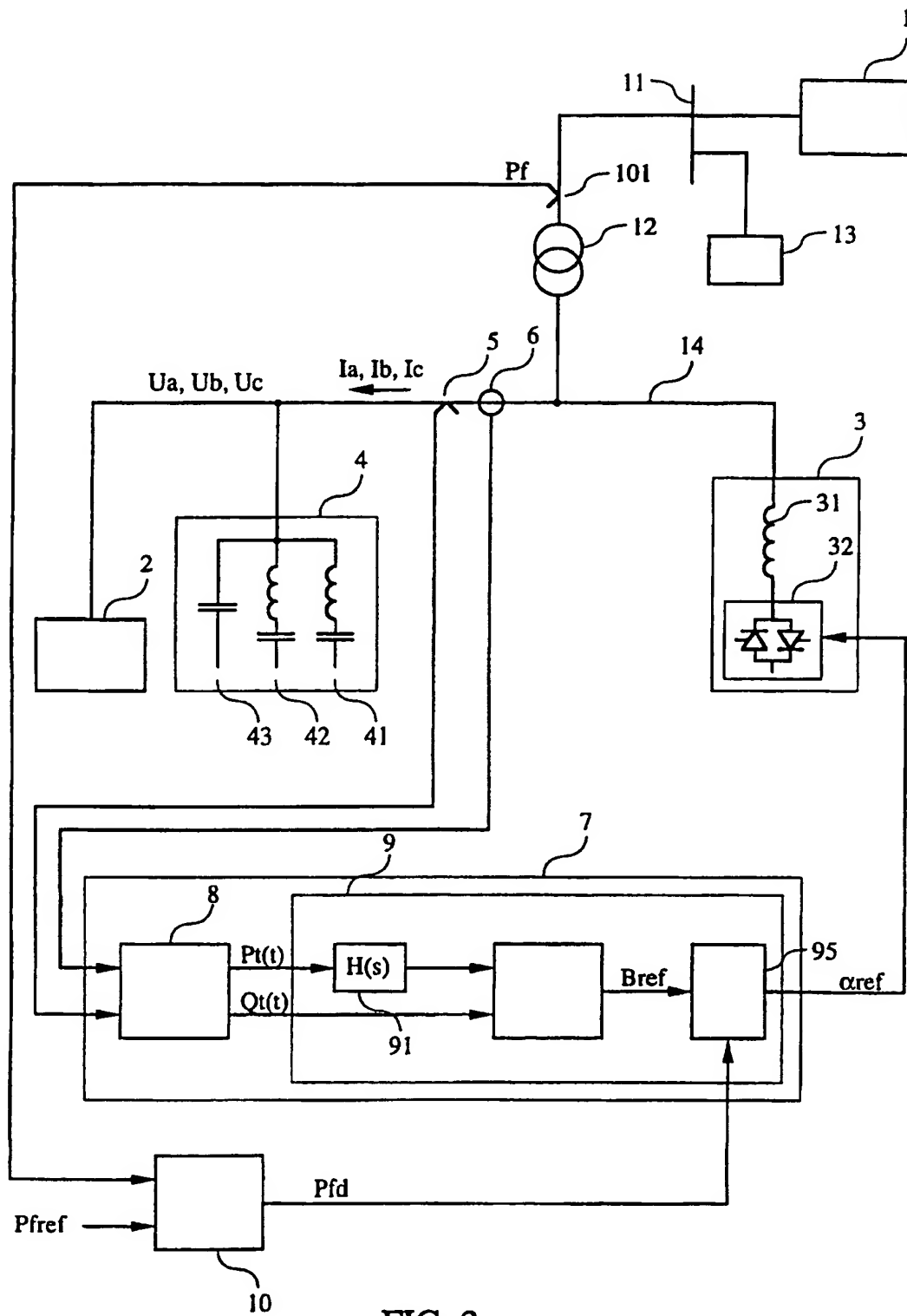
FIG. 1

FIG. 2A

FIG. 2B

FIG. 4

3/3

FIG. 3

1

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H02J 3/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H02J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0260504 A2 (KABUSHIKI KAISHA TOSHIBA), 23 March 1988 (23.03.88), see the whole document --	1-9
A	US 5138247 A (Y. TANOUE ET AL), 11 August 1992 (11.08.92), column 1, line 10 - column 2, line 54 --	1-9
A	EP 0519635 A2 (HITACHI, LTD), 23 December 1992 (23.12.92), abstract -- --------	1-9

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

*	Special categories of cited documents:
"A"	document defining the general state of the art which is not considered to be of particular relevance
"E"	earlier document but published on or after the international filing date
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O"	document referring to an oral disclosure, use, exhibition or other means
"P"	document published prior to the international filing date but later than the priority date claimed

"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X"	document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y"	document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 October 1997	10.10.97

Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Håkan Sandh Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1992)

International application No.

PCT/SE 97/01005

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EP 0260504 A2	23/03/88	CA 1283167 A DE 3776740 A JP 63066617 A US 4752726 A		16/04/91 26/03/92 25/03/88 21/06/88
US 5138247 A	11/08/92	CN 1026375 B CN 1070774 A DE 69115191 D,T EP 0476618 A,B SE 0476618 T3 JP 4125711 A		26/10/94 07/04/93 15/05/96 25/03/92 27/04/92
EP 0519635 A2	23/12/92	CA 2071033 A,C JP 4367011 A KR 9705095 B US 5349522 A		15/12/92 18/12/92 12/04/97 20/09/94